BY MARTY FEUERSTEIN, POLARIS WIRELESS

The complex world of wireless E911

Ensuring that various technologies work seamlessly is critical when lives are at stake

Locating callers in an emergency is much more difficult in wireless than in the traditional wired world. After all, each wired phone line connects to a physical location, so finding the address is simply a matter of searching a database using the phone number. In the wireless realm, however, wireless carriers and emergency call centers must deal with the freedom of mobility—the caller can be almost anywhere in the coverage area.

However, locating the caller is only the beginning. The position information must then be routed to the correct public-safety entity to dispatch rescuers, passing through a number of hands to get there. In this article, we explore the technologies necessary for locating the caller as well as speeding the delivery of information to the appropriate public-safety answering point (PSAP). Ensuring these technologies work seamlessly is critical during an emergency when lives are at stake.

Figure 1

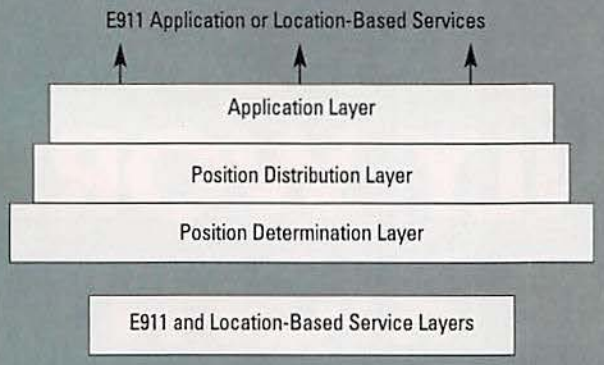
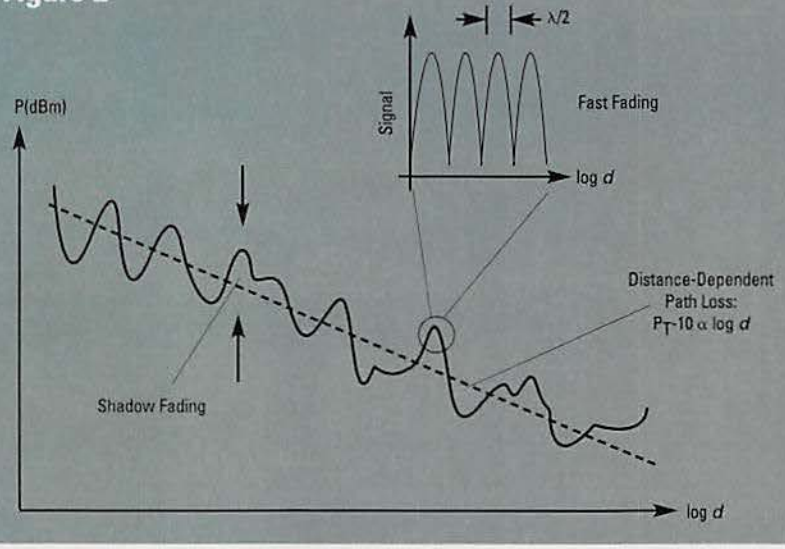


Figure 2



Locating wireless 911 callers is governed by the FCC's enhanced 911 mandate. According to the FCC's regulatory framework, network-based and handset-based location technologies may be used. Accuracy requirements differ for the two. We'll focus on a Polaris-developed network-based technology, wireless location signatures (WLS), which does not require changes to the handsets or base stations. Using this new software-only technology to locate callers enables the service provider to rapidly and economically roll out E911 service because there is no need to wait for new handsets to penetrate the market or new radio hardware to be installed in the network.

Regarding the transportation of location information, we'll focus on the world's most widely used air interface, GSM, to illustrate the critical flow of information during an emergency call. In GSM, there are mobile location centers (MLCs) to manage the process of locating the caller and notifying the PSAP. These MLCs must interact with both the radio network and equipment at the PSAP to coordinate the request and deliver the caller's location.

The E911 location service uses a layered model (Figure 1). The foundation level is the position determination layer. This is where the actual estimation of the caller's location takes place. In many ways it is analogous to the physical layer in an air interface. This is where the actual location technology comes into play: WLS, assisted global positioning system (AGPS) or time difference of arrival (TDOA). The position determination layer then hands the location information over to the

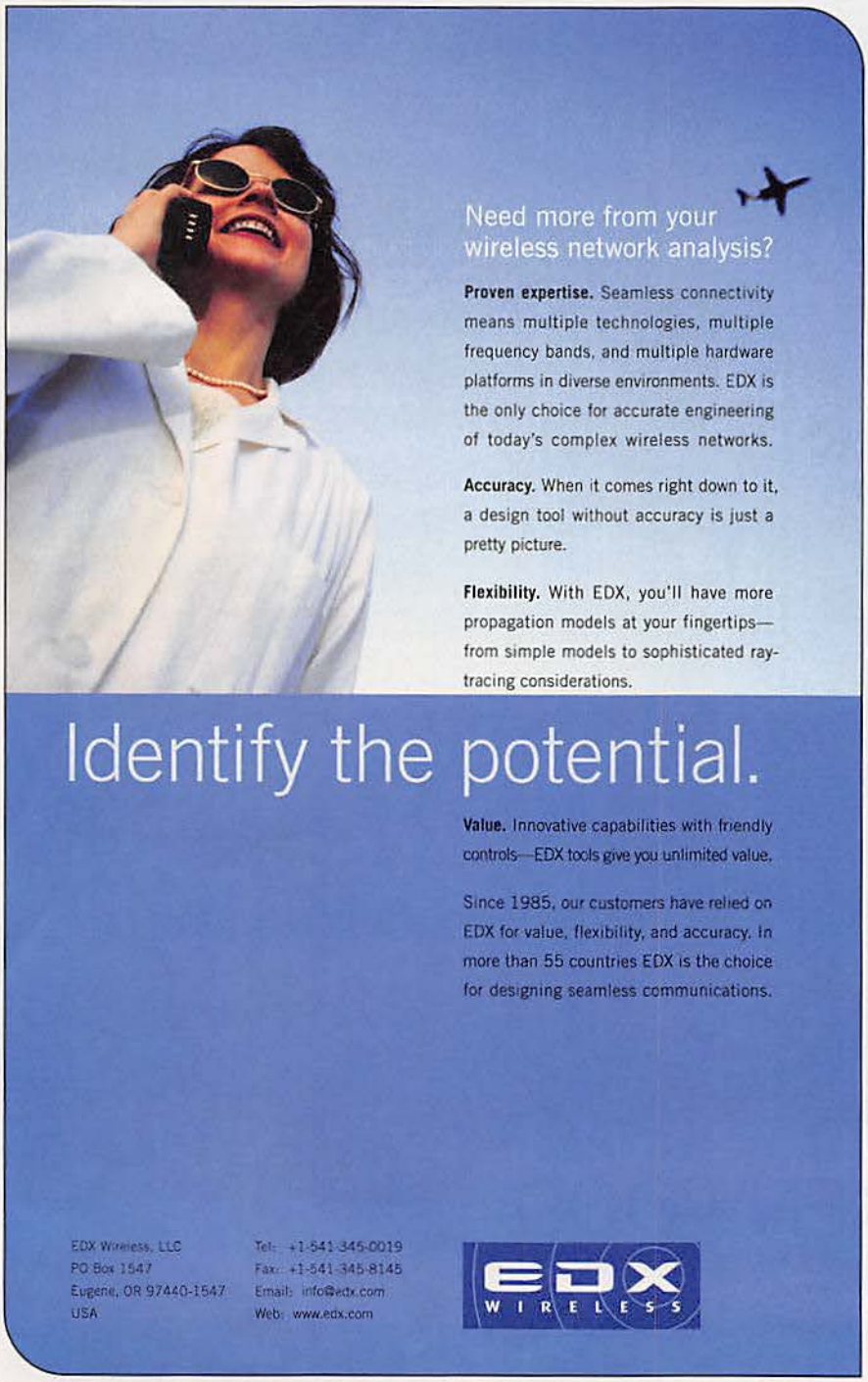
position distribution layer. This is where the location information is routed to the correct place, in this case the emergency service entity at the PSAP. Finally, the location information is handed over to the application layer for display and processing at the PSAP.

At the position determination layer, network-based or handset-based technologies are available to resolve the problem of locating the handset. The aforementioned WLS technology capitalizes on the signaling information already reported in the wireless network. In normal operations, handsets are continuously monitoring and reporting measurements of network conditions, such as signal strengths of cell sites, as part of the mobile handover process. These measurements create an RF "signature" that is unique for the handset's location (Figure 2). The radio signature results from unique characteristics of the path loss and shadow fading associated with multiple channels at each X-Y location. The averaging in the measurement process removes the fast fading components.

Using sophisticated statistical pattern-matching algorithms, WLS determines the location of the user based on a geographical predicted signature database (PSD). The prediction database is built from advanced propagation models tuned with calibration measurements performed at the time of deployment, assigning strengths to each channel at an X-Y grid square (Figure 3). In GSM, the mobile handover measurements—called network measurement reports (NMRs)—are sent to the radio network about every half-second throughout a call. During an E911 call, a number of these NMRs are aggregated to best estimate the caller's location by correlating against the PSD.

During an E911 call, these NMRs are aggregated to best estimate the caller's location by correlating against the PSD.

Figure 4 shows a conceptual, high-level diagram of the E911 system. The main components of WLS are the following: the PSD used for the pattern-matching to determine location, the location engine that performs the real-time position estimation calculations, and the real-time network interface needed to gather the NMRs and report the position. The interfaces to the PSAP and the carrier's radio network equipment are handled through the MLC. Software automatically maintains the PSD when the wireless carrier makes network changes, such as frequency plan modifications. Operation, administration, maintenance, and provisioning (OAMP) informa-


Need more from your wireless network analysis?
Proven expertise. Seamless connectivity means multiple technologies, multiple frequency bands, and multiple hardware platforms in diverse environments. EDX is the only choice for accurate engineering of today's complex wireless networks.
Accuracy. When it comes right down to it, a design tool without accuracy is just a pretty picture.
Flexibility. With EDX, you'll have more propagation models at your fingertips—from simple models to sophisticated ray-tracing considerations.
Identify the potential.
Value. Innovative capabilities with friendly controls—EDX tools give you unlimited value.
Since 1985, our customers have relied on EDX for value, flexibility, and accuracy. In more than 55 countries EDX is the choice for designing seamless communications.
EDX Wireless, LLC
PO Box 1547
Eugene, OR 97440-1547
USA
Tel: +1-541-345-0019
Fax: +1-541-345-8145
Email: info@edx.com
Web: www.edx.com
EDX WIRELESS

tion for the WLS system is available through Web interfaces at the carrier's network operations center (NOC).

A detailed diagram of the E911 network architecture is illustrated in Figure 5. The communications links between GSM elements are labeled using standard nomenclature from the 3GPP specifications. The heart of the position determination layer is the serving mobile location center (SMLC), where the location engine software resides to perform the calculation of the caller's position. The SMLC pulls the real-time NMR information from the base station controller (BSC) using an IP interface to the Abis probe units (APUs) and the Abis control function (ACF). Messaging with the BSC to coordinate the location process is performed on the 3GPP standard Lb interface over Signaling System 7 (SS7). On the back end, the SMLC has several IP interfaces to the NOC for database administration, network management and performance monitoring. The centerpiece of the position distribution layer is the gateway mobile location center (GMLC) which, working through the carrier's mobile switching center (MSC), handles the interfaces to the PSAP. The Emergency Service Network Entity (ESNE) handles the voice call path and the Emergency Service Management Entity (ESME) performs the necessary messaging to determine the location. The ESME is where the transfer to the application layer processing occurs, to display the location information for dispatchers. Once again, standard GSM interfaces are employed between the GMLC, SMLC, ESNE, ESME and MSC.

Figure 3

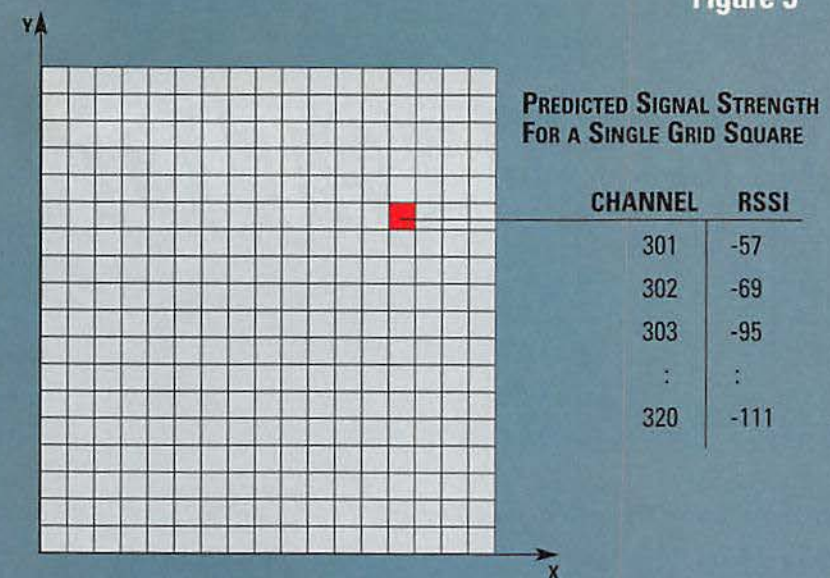
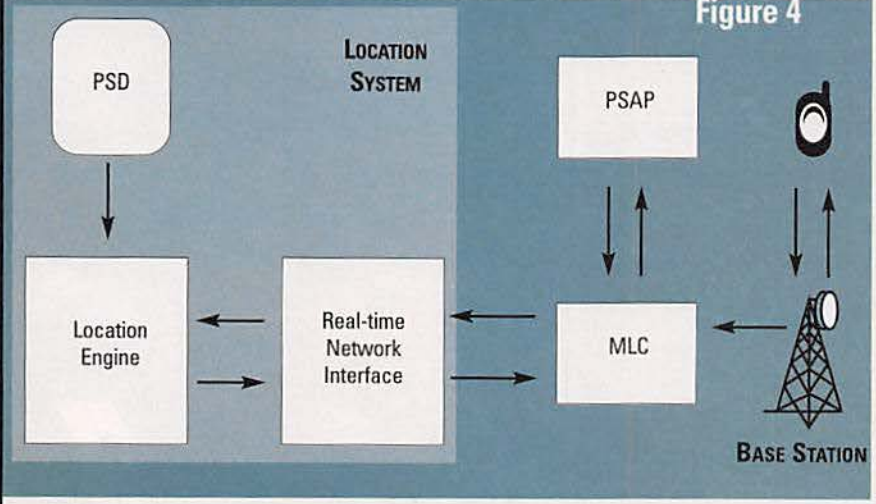


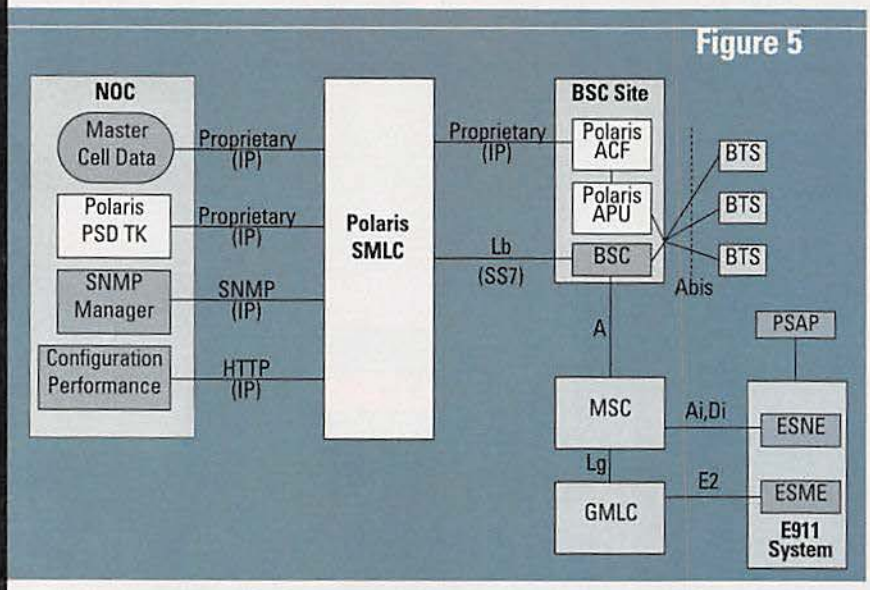
Figure 4



Now that we've identified the key elements and interfaces involved in E911 location determination, we can walk through what happens during an actual emergency call. It starts with the wireless subscriber initiating a 911 call. The BSC forwards the call request to the MSC, where a voice path is set up through the ESNE to the PSAP. At the same time, the call's NMR information is cached at the ACF for use in the position determination layer. Having identified this as an emergency call, the MSC requests that the BSC geo-locate the caller; the BSC then forwards the location request to the SMLC.

Once that happens, the SMLC queries the ACF to get both the cached and new NMRs. With the NMRs, the location engine in the SMLC calculates the caller's location. This triggers the SMLC to send a response to the BSC containing the caller's estimated location. The BSC then forwards the location to the MSC, which in turn forwards the position estimate to the GMLC. The ESME queries the GMLC for the location data and the GMLC responds with the position estimate. The ESME then transfers the location to the application software for display on the PSAP terminal. Finally, the PSAP communicates the caller's location to appropriate public-safety personnel.

During an emergency call, all of these network elements must work together seamlessly to speed the location information to the dispatcher and ultimately to the first responders. We've covered the wireless E911 process from the ground up. Let's recap: Starting with the position determination layer, we looked at how the wireless caller's

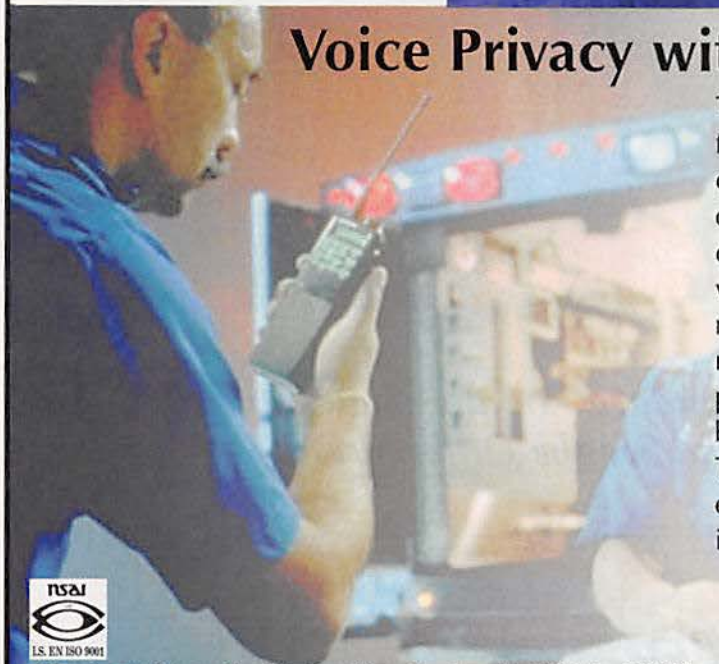


position is estimated using WLS technology. Sophisticated pattern-matching algorithms calculate the caller's location based on a unique signature reported by the handset. At the position distribution layer, the location information is routed through the carrier's network to the appropriate public-safety entity. A gateway serves as the interface between the carrier and the PSAP for transfer of the position information. At the PSAP, the application layer formats and displays the location information on the dispatcher's terminal screen. The dispatcher then communicates the location to the responding emergency crews, completing the final step in the process. Armed with the E911 caller's location, the first responders are far better prepared to deal with the emergency. And that's what E911 ultimately is all about—being ready to respond. ■

Marty Feuerstein is chief technical officer for Polaris Wireless, where he leads research and development of position-location products. He has more than 20 years experience in telecom, including positions with Lucent, Metawave, U S West/AirTouch and Nortel Networks. Feuerstein also has consulted extensively in the wireless industry for companies such as T-Mobile and Ericsson, as well as a number of start-ups. He has a PhD in electrical engineering from Virginia Tech.

TRANSCRYPT® INTERNATIONAL
A division of EFJ, Inc.

FREE Radio Security Information Package!
(800) 228-0226 US
(402) 474-4800 Worldwide info@transcrypt.com



Voice Privacy with Integrity...Worldwide

Transcrypt - the worldwide leader in voice privacy for over 25 years - brings you the experience that comes from securing voice communications for over 10,000 radio systems in more than 120 countries. Transcrypt manufactures a scrambler for virtually every make or model of analog land mobile radio. Count on Transcrypt to provide the right security level for you - government, military, public safety, first responders or commercial business applications. ISO 9001 certified, Transcrypt brings you unparalleled product quality, engineering expertise, technical assistance and the industry's best service before and after the sale.

Distributor Inquiries Encouraged
3900 NW 12th Street, Lincoln, NE 68521, USA
www.transcrypt.com

U.S. EN ISO 9001

®Transcrypt International is a registered trademark of EFJ, Inc.© 2004